Critical Heat Flux Experiments for In-Vessel Retention External Reactor Vessel Cooling Strategy using 2-D Slice Test Section

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1. Introduction

In-vessel retention through external reactor vessel cooling (IVR-ERVC) is important strategy to prevent the release of molten corium outside the primary pressure boundary during severe accident.

The purpose of this study is to produce the experimental data to assess the coolability limits on external vessel wall and make comparison with other experimental data on large scale two-dimensional slice test section.

Especially, the top region of the head is the main concern of this study. If the metal layer is formed on the top of the oxide pool, the heat flux is highest on the interface of the metal layer and the vessel wall by focusing effect. We had special interests in APR1400 and the test loop was prepared for the 1/16, 1/10 and 1/5 scale two-dimensional and two phase flow experiments for IVR-ERVC strategy of the APR1400.

2. Experimental apparatus

To investigate the size effect of test section on CHF in small scale two dimensional slices, an experimental water loop and test sections were constructed. Figure 1 shows a schematic diagram of experimental water loop. The experimental water loop used in this study consisted of test section, heat exchanger, surge tank, preheater, pump, flow meter, lower plenum, test section and upper plenum.

Preheater had roles of inlet subcooling control and water reservoir. And through pump the condition of mass flux can be controlled and forced circulation was used in this study. Through lower plenum, water was injected to test section and steam was generated in test

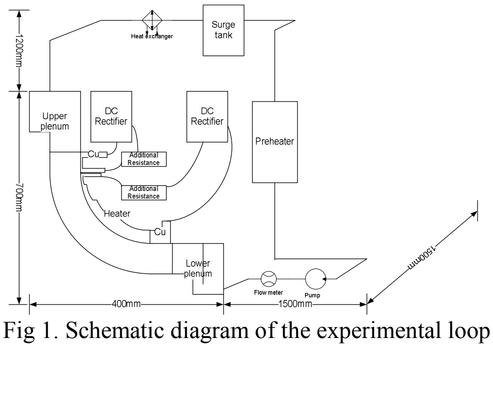

Fig 1. Schematic diagram of the experimental loop

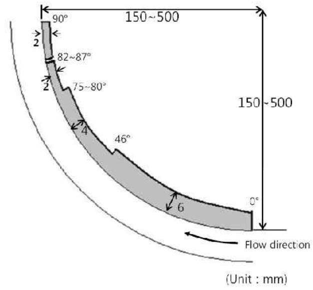

Fig 2. Test heater section geometry

section. The generated steam was condensed to water again in heat exchanger. The condensed water was gathered in surge tank.

The material of test section was Type 304 stainless steel used in KAIST-CHF experiments. In this study, three test sections of 15 cm, 25 cm and 50 cm were used. The shape was quarter-circle as shown in Figure 2. The test section was divided two parts. One part was the pre-heated region by direct current (DC) heating and had a connection with a 45 kW capacity DC rectifier. This part was divided three parts (thickness 2~6 mm). In pre-heated region, the heat fluxes were 280 kW/m^2 on a 6 mm thick region and 420 kW/m^2 on a 4 mm thick region. The maximum heat flux was 839 kW/m^2 on a 2 mm thick region. To control and maintain stably heat flux of the pre-heated region, an additional resistance was added in the circuit for DC heating. Another part of test section was main heated section. In this heated section, CHF was occurred. Using a 100 kW capacity DC rectifier, this part also applied DC heating. The main heated section was vertical plate. The heater thickness was 2 mm. This heater plate was also connected to additional. The experimental conditions of this study are summarized in Table 1.

Table 1. The experimental conditions of this study

Dimension of test section	**Radius**	15, 25, 50 cm
	Gap size	3, 6 cm
	Width	3 cm
Heating method		DC heating
Circulation method		Forced circulation
Pressure		Atmospheric pressure
Mass flux		100~300 kg/m^2s
Inlet subcooling		2 K
CHF point		90°
Working fluid		DI water

3. Results and discussion

Through this study, the CHF data of 3 points were measured for each test section under atmospheric pressure. The pressure at test section was ~1.15 bar due to hydraulic head by accumulated water along test section and surge tank. The obtained CHF data are compared with KAIST-CHF experiments and plotted in Figure 3 and 4.

As shown in Figure 3, the CHF on all test sections increases as the corresponding mass flux increases for consistent inlet subcooling. And the CHF also increases as the corresponding inlet subcooling increases for the consistent mass flux. As shown in Figure 4, for each test section when the exit quality decreases, the CHF increases.

When the inlet subcooling was 2 K, the CHF data of this study were slightly higher than that of KAIST-CHF experiments. The difference is 50~100 kW/m^2. However, the CHF value converged as the size of test section increases under consistent conditions. The CHF results on the small scale test section (radius of curvature; 0.15 m) are ~100 kW/m^2 higher than that on the real scale test section about the top of reactor vessel lower head.

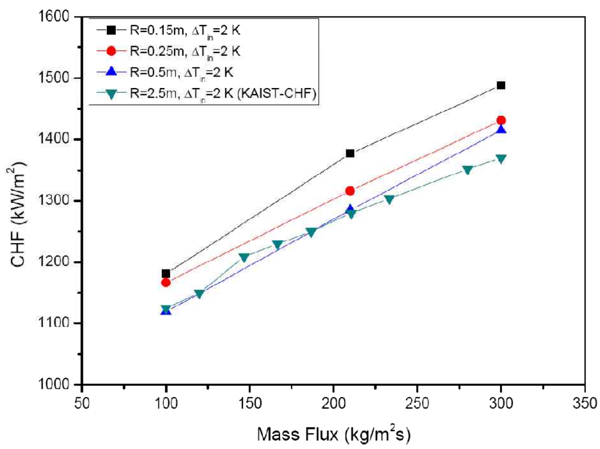

Fig 3. CHF data according to mass flux

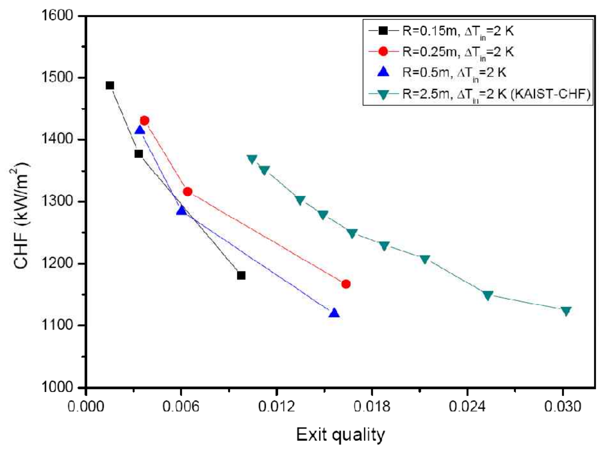

Fig 4. CHF data according to exit quality

4. Conclusion

Through this study, CHF experiments for IVR-ERVC using small scale two-dimensional slice test sections (radius of curvature; 0.15, 0.25 and 0.5 m) were conducted. Basically, the effect of mass flux, inlet subcooling and exit quality on CHF phenomenon was investigated. Especially, the comparison with large scale experiments (KAIST-CHF) was also examined.

For the inlet subcooling of 2 K, the CHF data of this study were 50~100 kW/m^2 higher than that of KAIST-CHF experiments. The CHF results on the small scale test section are 50~100 kW/m^2 higher than that on the real scale test section under mass flux conditions of 100~300 kg/m^2s.

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